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BULLETIN

OF THE

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The Comparative Anatomy of Corema alba and Corema Conradii.*

BY MARION C. MCEWEN.

(PLATE 210.)

The Order Empetraceæ includes but five species, all small evergreen plants with diœcious inconspicuous flowers and drupaceous fruit. They closely resemble one another and all have the general appearance of certain Ericaceæ. Of the genera now included in the Empetraceæ, Jussieu knew but one, and its resemblance to the Ericaceæ was so marked that he referred it to that order. Nuttall, on the contrary, in his description of the Empetraceæ, in 1818, considered them closely allied to the Coniferæ, while Don believed them to hold an intermediate position between Euphorbiaceæ and Celastraceæ. Dr. Gray, in the earlier editions of his Manual, placed the order between Euphorbiaceæ and Urticaceæ, while in the later editions it is put between Salicaceæ, with which it has little or no morphological connection and Ceratophyllaceæ.

In his description of the order, Dr. Gray indicates the questionable position of Empetraceæ by saying that it "has the foliage, aspect and compound pollen of heaths, the drupaceous fruit of *Arctostaphylos*, but the divided or laciniate stigmas, etc., of certain Euphorbiaceæ, and that it is "probably only an apetalous and polygamous or diœcious degenerate form of Ericaceæ."

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* Investigation conducted at the Botanical Laboratory of Barnard College.

Within the family the question of generic relationship has been the subject of discussion. Their close resemblance in morphological characteristics evidently entitles the five species to be classed in the same natural order, but under how many or what genera is not so clear.

There are three genera now recognized in the order, namely, *Empetrum*, *Ceratiola* and *Corema*. In the genus *Empetrum* are two species, *nigrum* aud *rubrum*, the former being circumboreal and widely distributed in high altitudes, while the latter is found in Southern South America. There is one species of *Ceratiola*, *C. ericoides*, which is found in the southern United States.

The genus *Corema* was named by Don after a careful study of the then so-called third species of *Empetrum*, *E. album*. This plant, which was discovered in Portugal, and as yet has been found only there and in the Azores, was from its general appearance and habit at first referred to *Empetrum*. Later Don found morphological differences in the new species, notably in the number of cells of the ovary, the kind of inflorescence and the lack of any proper perianth, which he considered sufficient to constitute a new genus. This he called *Corema*, giving us the third genus of the Order Empetraceæ with the one species *C. alba*.

Until 1837 these four species, under three genera, were the only representatives of this order known, the genus *Corema* not being known to occur in this country.

About that date Dr. Conrad found near Pemberton Mills, New Jersey, a small evergreen plant which he failed to identify. Specimens coming into the posession of Dr. Torrey he referred it to the order Empetraceæ, placing it in the genus *Empetrum*, noting at the same time its agreement in some particulars with *C. alba*. Dr. Torrey named the new species, in honor of Dr. Conrad, *E. Conradii* (Ann. Lyc. N. Y., 4: 83. 1837).

A little later Tuckerman sent very complete specimens of the new species to Dr. Klotsch in Berlin, who decided that it did not properly belong to any of the three genera of Empetraceæ, but constituted a new genus of the same order. Accordingly, he published a detailed description of the new genus, calling it *Tuckermania*, in honor of Dr. Tuckerman (*T. Conradii* Klotsch, Wiegm. Arch. 7: 248. 1842). But as this generic name had already been used by Nuttall, Tuckerman, in the same year, changed it to *Oakesia*, in honor of Dr. Oakes (*O. Conradii* Tuckerm., Hooker's Lond. Journ. Bot. 1842).

In the meantime Dr. Torrey and Dr. Gray had critically studied the plant in this country from fresh specimens, and they both became convinced that the new species agreed in all important characteristics with *Corema alba*, and accordingly in 1842 Dr. Torrey changed the name to *C. Conradii* (*C. Conradii* Torr.; Loud. Arb. Brit. 1092. 1842), and it has since remained under that genus.

We have, therefore, in the genus *Corema* two species ; the one, *alba*, confined to Portugal and Azores ; the other, *Conradii*, found only along the eastern coast of the United States, in widely separated localities, from Newfoundland to New Jersey.

Accepting the evolutionary idea of the origin of species, a puzzling question arises as to the genetic relationship between these two species, their geographical distribution being difficult to reconcile with the idea of a common origin.

The morphology of the two has already been carefully studied and described ; their comparative anatomy, however, has not been considered. In view of the importance now given to anatomical characteristics in plant classification, the comparative anatomy of these two plants has been an interesting study, and it is the purpose of this paper to give some of the results of such a study.

It has been impossible with the material available to follow the development-history of the tissues from their origin in the embryo, and the anatomy of the root has not been attempted, but a comparative study of the tissues of the fully developed stem and leaf has revealed some points of resemblance and difference from which conclusions may be drawn as to relationship.

The thick, deeply-grooved, evergreen leaf of *C. alba*—the type of the genus—is about 1 mm. broad, and, including the short petiole, 7 mm. long. It somewhat resembles the small leaves of some Coniferæ. A cross-section of the mature leaf (Fig. III.), under the microscope, shows the morphology to be strikingly different from that indicated by the outward appearance. Instead of a solid mass of tissue, as it seems to the naked eye, we find a flat leaf with its blades rolled under and the edges turned in so that only the upper surface of the leaf is visible from without, the lower surface lining the cavity thus formed. The groove on the under surface of the leaf is the narrow slit-like opening left between the rolled-under blades through which the lower surface of the leaf has direct communication with the air. The anatomy is in general that of the typical dicotyledonous leaf, but with some peculiarities to be described in detail.

Beginning with the upper epidermis (Fig. V.), the enormous size of its cells and the extreme thickness of the outer wall are first noticed. By actual measurement this outer epidermal wall, in some instances, equals one-fifth of the entire distance from the upper to the under surface of the leaf. The epidermal cells are further distinguished (Fig. V.) by a thickening of the walls which projects into and partially fills the lumen. These projections are sometimes in the form of irregular masses, but oftener the walls are thickened regularly, some time nearly filling the lumen. In all cases these thickenings, together with all the walls of the epidermal cells, except the sharply defined outer layer of the upper wall, respond to the tests for cellulose. The outer layer shows a cutin reaction. The mesophyll tissue consists of two layers of palisade cells and spongy tissue below of irregular branching parenchymatic cells with very large intercellular spaces. The lower epidermis, unlike the upper, consists of cells of ordinary size, and these are interrupted by numerous raised stomata. The entire lower surface of the leaf is thickly covered with hairs of two kinds—long, one-celled, thick-walled hairs, and three–five-celled capitate glands. The simple hairs predominate. The vascular system is simple, the shape of the leaf being such as to require but little supporting tissue. At regular intervals lateral bundles branch from the stout midrib, and there is a mere trace of bundles forming the net-veining of the dicotyledonous type. An entire absence of bast cells is a peculiarity of these bundles, a circumstance not remarkable in a leaf which needs so little strengthening element. An endodermis of somewhat thick-walled cells encloses the whole vascular system, separating the bundles from the surrounding tissues.

The leaf of *C. Conradii* is smaller and is minutely denticulate on the apparent margins, but otherwise it has the same outward appearance as the *alba* leaf, that of a thickened evergreen leaf deeply grooved on the lower surface. A cross-section, however (Fig. IV.), shows its morphology to be very different from that of *alba*. The leaf of *alba* is flat, with its blades rolled in such a way as to simulate a thickened leaf; that of *Conradii* is really thickened. That is, the central portion of the leaf is thickened and the edges of the blade are abruptly turned under, their margins nearly meeting below the lower surface, forming a furrow and leaving a small triangular cavity along the lower surface. As in *alba*, only the upper surface of the leaf is visible from without, the lower surface lining the cavity.

Comparing now the anatomy (Fig. VI.) with that of *C. alba*, we find the cells of the upper epidermis unusually large and with the outer wall thickened, though usually not so much as in *alba*. These cells agree with the epidermal cells of *alba* in having the cellulose thickenings in the lumen. These growths occur in the remarkably large lumen of cells which have to sustain the weight of a heavily thickened cuticle. For this reason it would seem that their function is that of mechanical support, performing the same office that similar growths do in the lumen of some large tracheæ and other thin-walled cells which have to sustain the pressure of heavier tissues. In certain families, notably the Urticaceæ, there is often a deposit on the inner surface of the wall of the epidermal cells in the form of cystoliths. The growths found in the cells under discussion, however, show none of the chemical reactions of cystolith formations, but in both species seem to be pure cellulose. The mesophyll tissue is like that found in *alba*, its development corresponding to the morphology of the thickened *Conradii* leaf. The same simple vascular system occurs; the bundles have no bast element, and the whole is enclosed by the endodermis sheath.

Coming to the lower epidermis, with its accompanying stomata and hairs, some differences are seen, although there are the same epidermal cells of ordinary size, the distinctly raised stomata, and the two forms of hairs—the long, one-celled hairs and the three-five-celled capitate glands that are found in the *alba* leaf.

The first difference noticed is the position of the simple hairs. Instead of being mingled with the glands over the whole lower surface of the leaf, they occur here only along the very edges of the incurved margins. These long hairs project from either margin in such a way as to interlace along the whole length of the groove on the lower surface of the leaf. There is also a great increase in the number of the raised stomata.

For the anatomy of the stem, sections were made in both species from shoots of one year's growth. Again, beginning with a description of *alba*, a cross-section shows, in general, the structure common to woody dicotyledonous stems of that age. Both species are alike in that there is no periderm formation the first year, but the epidermis remains until the formation of the second year's wood. This is somewhat unusual, because in stems where a periderm is formed it is likely to appear very early in the first season.

The epidermis, in the *alba* stem, consists of cells of ordinary size with the outer wall thickened and cutinized and the thickening extending into the radial walls. Next to the epidermis is the zone of cortical parenchyma, which varies in depth from two to several layers of large cells. Separating the cortical tissue from the central cylinder is a distinct layer of cells one layer in width. These cells have a longitudinal diameter about four times that of the radial and tangential, and their outer tangential walls are much thickened. Their walls also respond to the test for suberin, and they correspond to the endodermis sheath which DeBary describes as occurring in the stems of some woody dicotyledons. The phloem zone is narrow and, like the phloem of the leaf bundle, is peculiar in having no bast elements. The cambium zone is about two rows of cells in depth. The libriform cells have bordered pores in abundance on both their tangential and radial walls, but no simple pores. The ducts are numerous but not of unusual diameter for wood of this character, and they too have bordered pores and a few have spiral markings. Towards the pith are crowded the narrow tracheids which show both ring and spiral sculpturing. The medullary rays are one cell in width, and the pith cells are of the ordinary type.

Sections of the *Conradii* stem show a structure similar to that of *alba*. Its deviations from the typical dicotyledonous woody stem, like those of *C. alba*, are an endodermis sheath, an entire absence of bast tissue, and the presence of only bordered pores in the libriform cells. This occurrence of only bordered pores in the libriform has been found by Dr. Gregory to be a characteristic common to the orders Empetraceæ and Ericaceæ—a fact which may bear upon the question of relationship between them.

This examination of the anatomy of the stem and leaf of the two species brings us to the question, What does it indicate regarding the relationship between *Corema Conradii* and *Corema alba?* Considering only the anatomy of the two stems, it leads decidedly to the opinion that they are species of the same genus. This relationship is not so strongly indicated, however, by the character of the leaves.

Taking *alba* as the type of the genus, the variations from the type shown in the *Conradii* leaf would indicate an adaptation of that plant to a changed environment rather than an original generic difference. This plant, *C. Conradii*, has apparently adapted itself to a climate subject to drought and extremes of heat and cold. This is first shown by the thickening of the leaf, whereby the working tissues are more compactly arranged and a smaller surface is exposed. To provide against long continued drought, there is an arrangement similar to that found on leaves which are known to need protection from excessive evaporation. The long hairs before referred to, which are found only on the very edges of the *Conradii* leaf, interlace, forming a felt-like mass, with only capillary spaces through which the lower surface of the leaf has communication with the air. This regulates the amount of evaporation from the stomata by retarding the escape of moisture from the channel inside, while at the same time, by retaining the heat given off, it protects it against the cold.

On the other hand, this arrangement of hairs, which prevents evaporation and raises the temperature of the leaf, hinders the free interchange of gases. This, again, is remedied by the raised stomata. If the stomata were sunken, or even level with the epidermis, it would be difficult to effect the proper circulation inside the tissues. Hence the development of the raised stomata, which, by their form, allow a freer passage of air in and out. Furthermore, there is a great increase in the number of stomata over those on the *alba* leaf.

The leaf of *C. alba*, though similar in many respects, does not show the same adaptation to extremes of climate. It is more nearly flat, thus exposing a larger surface. The rolling under of the blade and the growth of hairs on the lower surface form a protected cavity which, in a measure, regulates the amount of evaporation through the stomata, but still the air has free access to the whole surface. Here again are the raised stomata, but much fewer in number. In one respect, however, this leaf is better prepared for extremes of temperature, namely, the enormous thickness of the cutinized outer wall of the upper epidermis, which even exceeds that of *Conradii* in most instances.

The leaf is the first organ where we should expect to find changes for the accommodation of the plant to a changed environment. It is primarily the organ for the individual uses of the plant, for through it is obtained food material from the air, and in it the chief processes of metabolism are supposed to take place.

Again, it is the metamorphosed leaf which is used for the reproductive processes of the plant. Here the leaf gives up its function as the servant of the individual and its energy is turned to the perpetuation of the species. In the whole life history of a plant species the leaf is the inconstant organ, changing its form and function for the varying needs of the individual and the species. The stem, on the contrary, is the constant organ. It is, therefore, to the anatomy of the stem, rather than that of the leaf, that botanists attach the first importance in the determination of relationship. In the same genus only the slightest variations are expected in the anatomy of the stems of the different species.

In the two species under discussion the stem of *Conradii* agrees with that of *C. alba* in all particulars, showing the same deviations from the normal dicotyledonous type. The leaf of *Conradii* has all the peculiarties of *alba* shown in the raised stomata, the two sorts of hairs, the extremely thick cuticle, and the unusually large epidermal cells with the strengthening projections of the cellulose wall. It disagrees in ways which indicate adaptation to environment rather than difference in origin.

Therefore, the result of the comparative study of the tissues favors the classification already made of these two species.

In view of the resemblance between the orders, a comparison of the anatomy of the species of Empetraceæ with the typical Ericaceæ would be an interesting study, and this we hope to accomplish.

Explanation of Plate 210.

FIG. I. Leaf of *C. alba*, lower surface. a. Groove.

FIG. II. Leaf of *C. Conradii*, lower surface. a. Groove.

FIG. III. Outline of cross-section of leaf of *C. alba*.

FIG. IV. Outline of cross-section of leaf of *C. Conradii*.

FIG. V. Portion of a cross-section of a mature leaf of *C. alba*. a. Thickened cuticle. b. Lumen of the large epidermal cells. c. Thickenings of the cellulose wall of epidermal cells. e. Raised stomata on lower surface. f. Simple hairs. g. Glands.

FIG. VI. Portion of cross-section of a mature leaf of *C. Conradii*. a. Thickened cuticle. b, b. Lumen of epidermal cells. c, c. Thickenings of cellulose wall of epidermal cells. d. Midrib. e. Raised stomata. f. Simple hairs. g. Capitate glands.

FIG. VII. Cross-section of stem of *C. alba* one year old. a. Epidermis. b. Rind parenchyma. c. Endodermis.

Some New and Rare Desmids of the United States.—I.

BY L. N. JOHNSON.

(PLATE 211.)

During the last two or three years the writer has examined quantities of material rich in Desmids from various parts of the country. Among the species noted are some rarities, while a few are apparently unrecorded from the United States, and several are undescribed. It is not my purpose here to give complete lists of all species found, but merely to mention some of the most interesting "finds." The Connecticut specimens mentioned, unless otherwise stated below, were collected at Bridgeport, those from New York at Cold Spring Harbor and the Michigan material at New Baltimore. Curiously enough in these gatherings some of the species recorded by Wolle as common have proved very rare, or have not been seen at all. For example, *Tetmemorus Brebissonii* (Menegh.) Ralfs. has been found but once, and then but a

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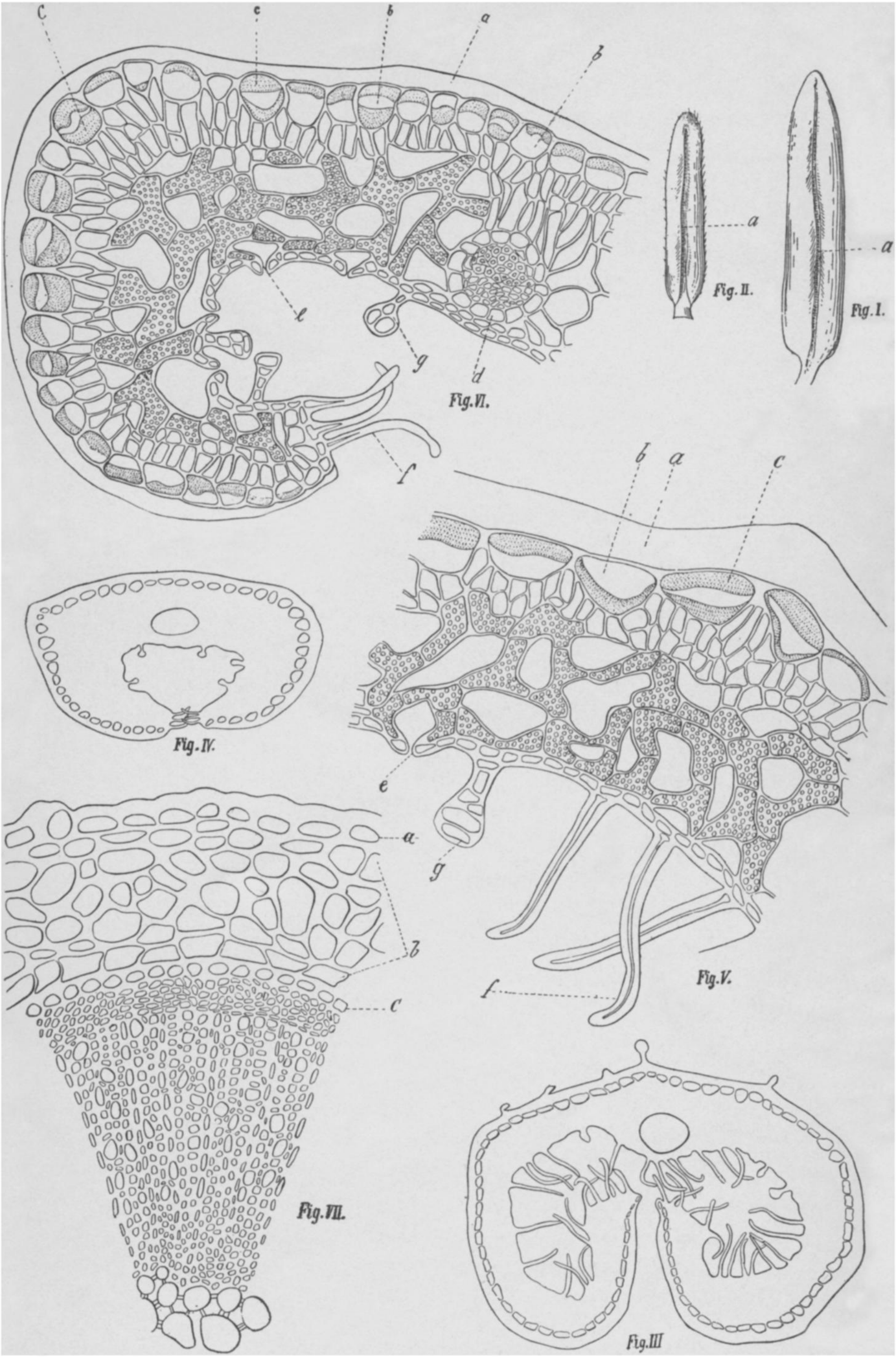

COMPARATIVE ANATOMY OF COREMA.